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DISEASES

OF

CEREALS IN UGANDA

BY

W. SMALL M.B.E., M.A., B.Sc., F.L.S.,

Mycologist

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DISEASES OF CEREALS IN UGANDA

The present circular gives an account of the diseases of cereals in Uganda as far as they have been investigated. In past years little or no time was available for their study, but recent circumstances have allowed the work to be taken up, and the results are here presented. It will be noted that many well-known cereal diseases are not recorded. Several may not occur in the country, but there must be others whose presence has yet to be disclosed. The present survey does not, therefore, pretend to be complete, but it is hoped that the material of this circular will prove of interest, as it stands, to administrative and agricultural officials in the Protectorate, and to others who have taken up the growing of cereals such as maize.

It is not to be imagined that all the parasitic fungi discussed are the cause of serious losses. Several are always present in greater or less amount, and they may lead to damage which at times appears to be serious, but they are not worthy of being regarded with great alarm. Others, again, do regular harm by consistently reducing the amount of crop. Examples of the former class are the maize rust caused by *Puccinia sorghi* and the *matama* leaf spots, while examples of the other class are the wheat rusts and the blast disease of rice. The inclusion, however, of any one parasite in either class is not a rigid matter, for the maize rust, say, may cause at times sufficient harm to warrant it a temporary place in the group of dangerous diseases. It is, therefore, one of the objects of this publication to impart, not minute technical knowledge of the various parasites of cereal crops in Uganda, but rather a general idea of the place in the economy of nature of the fungi concerned and of their influence on the circumstances of their hosts, so that there may be developed a point of view towards the diseases of native crops which is both practical and sound.

It may be said at once that direct remedial measures, such as spraying, are impracticable, if not entirely impossible, in the treatment of the diseases listed, and that the attention of all concerned with native agriculture cannot be too strongly directed to the possibilities of improvements, often apparently trifling, in ordinary practice, and to the usefulness of certain simple measures of control. In dealing with natives, it will

be for many years more practical to endeavour to induce the adoption of measures of control than to impose upon the cultivators the necessity for directly attacking the fungous enemies of their crops, on the principle that steps taken to improve the general health of the plants are, in general, steps against their parasites. Such steps should consist of the protection of new crops against infection from old by the destruction of all diseased material, and of good cultivation which will increase the vigour of the plants and lead to a state of resistance to disease.

Plant diseases can be divided roughly into two classes, controllable and uncontrollable, and the determination of the nature of any disease is a matter for the expert. For others, *it is at all times preferable to concentrate on the host plant* on the lines laid down above, with a view to assisting it in its struggle against its enemies. It should be kept in mind that the fungous parasites of agricultural plants are always lying in wait for opportunities to attack, and it may be wondered why diseases of cereals are not more in evidence. They are, in fact, always present, but the damage caused by them is not infrequently so slight to the eye that it passes unnoticed, or is regarded, through lack of knowledge, as a normal state of affairs. The losses of food stuffs in ordinary native plots from year to year must be enormous, and there is no doubt that the difference between what the native actually obtains from his cultivation and what he ought to obtain would be astonishing if it could be reduced to figures. The whole responsibility for the loss cannot be laid at the door of the parasitic fungi, for the ravages of insects and the gradual deterioration of crops must be taken into account. With these goes a lessening of the power of resistance which may be succeeded by such general weakness that the plants fall an easy prey to their fungous enemies. The principle of rotation of crops is generally understood, and the practice of rotations in native crops should be encouraged. The native custom of growing several crops together in a comparatively small area is not to be entirely deprecated, for a mixed cultivation is always less liable to an epidemic of disease than a single crop. Nevertheless, there is room for modification of the usual practice, and open planting should be advised in order to avoid the atmospheric humidity that favours the rapid development of certain fungi, for example, rusts. Certain varieties of crops are known to be more resistant to disease than others, and they should not only be encouraged but distributed for trial from one part of the country to another. Much could be done in this direction by scientific *plant-breeding. General sanitation, reduced to ordinary cleanli*ness, the destruction by burning of all rubbish, such as uprooted crops, that might and does harbour both fungous and insect pests, should be put into practice, and good cultivation should be encouraged. The habit of leaving standing plants after the crop has been harvested is not a good one because the plants are liable to breed out fresh crops

of the spores of leaf rusts or other fungi which may be present on them, and so ensure infection of the next planting. Again, there is often great advantage in the early recognition of plant disease and the removal of affected individuals, as in, for example, downy mildew of maize, and the process is rendered all the easier in small native gardens.

The writer must admit that he has usually found it a difficult matter to explain even to educated chiefs the simplest details connected with the life of a parasitic fungus, such as, for example, the fact that the plant-body or *mycelium* of the parasite is within the host and, because of its position, unattackable unless the host is also destroyed, the further fact that this plant-body produces its spores on the surface of its host, whether leaf or stem, the third important fact that these spores must be destroyed because it is by their agency that fresh generations of the parasite are given a start in life, and the fourth fact that a simple and practical way in which this last can be done is by thorough burning of all rubbish, especially infected rubbish. There is, however, no reason why technical officers should not endeavour to spread knowledge on the above lines through the medium of chiefs and instructors, and it is the considered opinion of the writer that a beginning should be made *now* in no matter how small a way.

The fungi affecting the various crops are discussed under the headings of their hosts—*sorghum*, *maize*, wheat, bulrush millet (*Pennisetum typhoideum* Rich), *buro* (*Eleusine coracana* Gaertn.), and rice.

Millet (*Andropogon Sorghum* Brot.), *muwemba, matama.*

DOWNY MILDEW (*Sclerospora* sp.)—This disease is not common, but infected plants can always be found here and there. It was recorded previously from German East Africa, and doubtless it is to be found over this part of the continent, although there is no record of it from Kenya. The majority of the cases examined have been young plants. The effects of the disease are therefore less well-known on older plants, but sufficient evidence has been gathered to show that there are at least two distinct types of downy mildew. In young plants, the disease may appear very early. The leaves are pale and narrowed and eventually marked with light-coloured streaks along which tearing takes place. They may also be crinkled and folded, and the young lateral shoot-buds of the stem do not grow out normally, but are held fast within the sheaths which are themselves much deformed. The plants remain stunted and are sterile. On older plants, the attack takes the form of pale areas and streaks and darker patches on the leaves, which become almost brown in colour, but do not tear into shreds. The ears may develop normally in this form of the disease, or they may be, as shown in Fig. 1, much smaller than in the healthy plant. At the same time, the buds on the stalk may be as described above. This

mildew has been found on young plants in small groups, but only singly on older plants, so that it would appear to be communicable from one plant to another under certain circumstances. It has not yet been noted in an epidemic form.

The causal fungus can be found in two stages. The first of these consists of a fine white mildew, the conidial stage of the fungus, which occurs on the leaves, usually on the under surface, but which is evanescent and not easily found, and the second of oospores which occur in the browned parts of the leaves. The oospores are smaller than the sizes given for those of the *Sclerospora* that causes downy mildew of sorghum in India, and it is possible that the Uganda fungus is a distinct species.

This downy mildew cannot be considered as serious, but all affected plants should be uprooted and burned. The burning is important in view of the presence of the oospores in the leaves. If this treatment were to be carried out systematically in all native gardens, the disease would probably be eradicated from the country in a comparatively short time.

RUST (*Puccinia purpurea* Cke.).—This rust of sorghum is exceedingly common in Uganda and is well-distributed in countries where the crop is grown. It has not yet been found on maize or any wild grasses. Despite the statements made with reference to its harmfulness in other countries, the damage caused by it in this country is problematical, for bad cases of infection are most often found on the lower worn-out leaves. Nor is there any evidence of its being responsible for short cropping. It seems to be commonest when the host plants are nearly mature.

The presence of the rust is shown by purple-red leaf spots on the undersides of which the fungus breaks out in the form of pustules. The pustules may be of two kinds containing two distinct kinds of spores, or both spores may occur on the one pustule. The spores are shown greatly magnified on the right in Fig. 2. The lower figure is that of the uredo- or summer-spores which serve to spread immediate infection, and the upper figure that of the thick-walled septate teleuto- or winter-spores which in many rusts are capable of passing through a resting period in the soil and so of carrying the fungus over times when no host plant is available. The teleutospores have been germinated artificially but no infection experiments have been carried out with them, and it is not known what part, if any, they play in the life history of *Puccinia purpurea*. It is probable that they are unable to infect, and that their original function is falling into disuse because they are no longer required under local climatic conditions. When the native sows successive crops of sorghum during the year, the rust has an easy chance of persisting from crop to crop and of becoming really harmful. The usual custom, in Buganda at least, is to sow two crops during the year at intervals of about six months, and the fungus is therefore able to take advantage of one host after the

other. This fact may have some bearing on the probable loss of function of the teleutospores of the fungus inasmuch as the disease can be propagated from crop to crop by the uredospores alone. No direct treatment of sorghum rust is practicable, but all plants should be uprooted and burned immediately after the crop is harvested.

RED LEAF SPOT (*Colletotrichum graminicolum* (Ces.) Wils.).—The spot caused by this fungus is common and is often found in this country on older leaves of sorghum associated with the rust discussed above as well as on younger leaves as an independent parasite. The spots are red, smaller than those of the rust, and usually of a lighter colour towards the centre. As each represents a localised infection, the damage done is never great, and treatment should be advised as for the sorghum rust above.

Fig. 3 shows the spots on a piece of leaf and the setæ and spores of the fungus as they can be found on the spots after the fungus has broken through to the surface of the leaf. Three spores are shown germinating and forming the dark, more or less rounded appressoria which help in producing new infections by acting as penetrating agents of the leaf-surface on which they alight.

LEAF BLIGHT (*Helminthosporium turcicum* Pass.).—This leaf blight is less common than the rust and red spot mentioned above, but it can, nevertheless, usually be found in association with *Puccinia purpurea* and *Colletotrichum graminicolum* on worn-out leaves. It has been found in India, Egypt and other countries, and it occurs in Uganda also on maize, on which host it is more destructive than on sorghum. It is scarcely necessary to advise treatment, but it may be said, with reference to the leaf blight and the other leaf diseases given already, that rotation of crops is always safely to be advised as an extra measure when the effects of these diseases are apparently serious, and that the cumulative effect of the continued burning of diseased leaves season by season is a valuable means of control.

GRAIN SMUT (*Sphacelotheca sorghi* (Link.) Clinton).—Two smuts of sorghum have been found in Uganda, the grain smut and the head smut. The grain smut has been reported from several districts and is much more common than the other At times it causes great loss, for whole plots have been ruined by it, and it is usually found to have affected a large percentage of the exposed ears, to which part of the plant it is confined. The value of the grain destroyed by it in the Bombay district of India was estimated at one time to exceed a million pounds sterling per annum. In affected heads, small grey-black sacs are found to have replaced a proportion or the whole of the grains. The sacs are full of a black powder consisting of the spores of the fungus, and if, as usually happens, they rupture before harvest-time, the black powder so displayed renders the smutted ear conspicuous while the plants are still standing. In Fig. 4, No. 1

represents a smutted ear, Nos. 2-5 show the effect of the disease on individual flowers of the ear in their development into spore-sacs of different types, and Nos. 6-11 represent the results of germination of the spores. In No. 3, the spores have been shed from the sac and the central black column which remains is disclosed. This column is part of the host plant. The stamens of the flower shown in No. 4 may be so involved in the changes wrought by the smut that they eventually resemble the lobes shown on the spore-sac in No. 5.

Infection of sorghum by the grain smut occurs only during the time that elapses between the germination of the seed after sowing and the appearance of the young plant above ground. It is brought about by smut spores which have adhered to the surface of the grain and so been planted along with the seed, and the fact that the plants are infected is not disclosed until the ears have begun to form.

As it seemed desirable to ascertain the behaviour of the spores of this destructive smut in Uganda, germination tests have been made at different times. It has been found that the spores germinate readily to the extent of eighty per cent in five days at ordinary temperatures on soil or filtered paper moistened with rain water, and that they are killed by contact with one per cent formalin or two per cent copper sulphate solution. It is to be deduced from these facts that formalin and copper sulphate will supply two easily-made and easily-applied sprays for both plants and plots, and that showery weather in itself will control the amount of smut by causing the germination of the spores that have fallen to the ground or are lying on the leaves or stems of the plants. The germination of the spores under such circumstances is harmless because the spores can attack and penetrate only young plants. Fuller control of the disease could be got by seed-disinfection before planting, a measure which has been adopted with success in parts of India where packets of copper sulphate containing enough of the chemical to treat the seed required for four acres of sorghum are sold to native cultivators at one anna each. Should the grain smut ever become as destructive in Uganda as it has been in other parts, such seed-treatment as has been mentioned would have to be adopted. At present there is, fortunately, no necessity for it. Diseased plants should be burned, and it may be advisable to plant up a new area with sorghum until the affected one has been well soaked by rain and rested for a short time.

Fusarium heterosporum Nees and *Darluca filum* (Biv.) Cast. frequently occur on the sori of *Sphacelotheca sorghi*.

HEAD SMUT (*Ustilago Reiliana* Kuehn.).—As already remarked, this smut is not so common as the grain smut. In India it occurs on maize as well as on sorghum, and it is known also in the United States and Europe. It is distin-

guished from the grain smut by the infection of the whole ear and of other parts of the plant, *e.g.*, the leaves, instead of the individual grains, and by its occurrence on a few scattered plants in a plot instead of on a group of plants growing together. Diseased plants grow normally and appear to be healthy until the time comes for the bud to emerge from its sheathing mass of leaves, when there is disclosed the large black mass of the fungus instead of the usual ear. Two examples of the effects of the smut on the ear are shown in Fig. 5. The covering membrane of the black sorus breaks easily and sets free the spores of the fungus, which are then dispersed by natural agencies. Unlike the spores of the grain smut, those which fall on the soil do not all germinate at once, but many remain dormant and in wait for the next sowing of sorghum. Other spores perish or find no opportunity of infecting a fresh host at the critical moment of their germination, and it is thus that the sporadic occurrence of the head smut is explained. Diseased plants should be removed from the plot and destroyed before the spores of the fungus are shed, and, in any case, sorghum should not be planted in the same place for several seasons.

Maize (*Zea mays* L.) *kasoli*

Downy Mildew (*Sclerospora* sp.)—The downy mildew of maize has caused great loss in Java and other eastern countries, and is regarded as a serious menace to the crop in the Philippine Islands. It cannot yet be said to be of a harmful nature in Uganda. In fact, it has been recorded only twice, but, it should be noted, on the South African varieties *Salisbury White* and *Potchefstroom Pearl*, as well as on native maize. The causal fungus has not been isolated from diseased plants, but there was no doubt of the symptoms being those of downy mildew. Infection can take place when the plants are young, but affected plants in Uganda have been well, though not fully, grown. The distinctive streaky whitening of the upper leaves due to the breaking down of their green colouring matter and their bunchy habit have been unmistakable. The disease proves fatal to affected plants. In the absence of study of this disease and knowledge of the nature and life-history of the parasite causing it, the only recommendation that can be given is that diseased plants should be uprooted and burned. This measure is easy of application because diseased plants are readily recognised among their healthy neighbours, and because, up to date, attacks have been only sporadic.

The fungi causing downy mildews have been studied in recent years on wheat, maize, sorghum, rice and sugar-cane among other hosts, and they are now recognised as of great importance in the economics of these crops. The above-advised destruction of diseased plants may therefore have a future significance out of keeping with the simple nature of the recommendation, for it is to be expected that outbreaks

of downy mildew will increase in number and severity as time goes on. Proof is accumulating that the sources of the fungi of downy mildews on cultivated crops are to be found on certain wild plants, and it is therefore only a question of time until the fungi concerned will accustom themselves to cultivated hosts such as maize. The results of a transfer of this nature, *i.e.*, from one plant to another, are usually very serious for the new host.

RUST (*Puccinia sorghi* Schw.).—Maize rust is very common at certain times of the year, particularly after the rains, and on occasions it has been found to damage the attacked leaves and to render the plants incapable of ripening their crop. In all such cases, the maize has been closely planted and the weather conditions moist and humid. This rust is known in India, parts of the United States and Australia, and it has been recorded from Kenya.

Fig. 7 shows the pustules produced on the leaf by the rust and the two kinds of spores of the fungus. When the pustules burst open by rupture of the epidermis of the leaf, the spores are disclosed as brown or black powdery masses. They are of the same two kinds as were mentioned under *Puccinia purpurea* of sorghum, namely, uredo- and teleutospores.

It is known to many that rust fungi may be *heteroecious*—that is, while the fungus passes part of its life on one host, as does *Puccinia sorghi* on maize, it requires a second distinct host in order to complete its full life-cycle. The spore which bridges the gap between the two hosts by infecting the second from the first is the teleutospore. In the black rust of wheat which will be mentioned later, the teleutospore produced on wheat in colder countries enables the fungus to pass to, and live a portion of its life upon, the barberry, and a third type of spore formed in turn on the barberry enables the rust to return to wheat, its first host. There is, therefore, a cycle of stages in the life-history of a typical rust, and in the cycle an intermediate host quite distinct from the original. The destruction of the intermediate host may thus be a useful and necessary part of the control measures directed against rusts. In this connection, it has been found in America, Europe, and South Africa that the maize rust passes from maize by the medium of its teleutospores to complete its life-cycle on plants of *Oxalis*, but attempts made to germinate the teleutospores of *Puccinia sorghi* with a view to finding whether they were capable of infecting *Oxalis* in Uganda proved abortive. Nor has any success attended efforts to infect *Oxalis* plants directly with both fresh and rested teleutospores or to discover on them indications of rust infection in nature. It is concluded, therefore, that the second *Oxalis* host of *Puccinia sorghi*, of which there is abundant material in the country, is not required under local conditions and that it has dropped out of

Diseased leaves should be stripped from the plants and burned, and in bad cases rusted plants should be wholly uprooted and destroyed.

Darluca filum, already mentioned under grain smut of sorghum, is commonly parasitic on the sori of *Puccinia sorghi*.

LEAF BLIGHT (*Helminthosporium turcicum* Pass.).—This disease is known wherever maize is grown and is probably commoner than any other affection of the plant. Serious damage has been done by it at times in the United States, Italy and the Philippines. In Uganda it is frequently associated with *Puccinia sorghi*, but independent attacks are not unknown. A bad attack will hinder the growth of the plants, but the effects of the blight are more often to be found only on the leaves in the form of spots and thin streaks and an eventual drying-up which leads to the loss of valuable leaf-surface.

Fig. 8 shows part of an affected plant as well as the spores, the branches on which they are borne on the surface of the leaf, and one germinating spore of *Helminthosporium turcicum*. After a bad infection of leaf blight, rotation should be practised and all diseased material should be collected and burned.

It has already been mentioned that leaf blight caused by the same *Helminthosporium* occurs on sorghum, but it is not known whether the two Uganda strains of the fungus are capable of infecting each the host of the other or whether each specialises in its own host.

Wheat (*Triticum* spp.) *n'gano*

BLACK RUST (*Puccinia graminis* Pers.).—Black rust of wheat is of wide distribution; it is, in fact, a constant companion of wheat wherever it is grown, and the monetary losses caused by its ravages year by year are enormous. A well-known Swedish authority has recently estimated the world's losses from cereal rusts at over sixty million pounds sterling per annum. Orange rust due to *Puccinia triticina* Eriks. is also common in this country, and practically all the wheat grown in Uganda is attacked by one or other rust, but seldom by both, to a greater or less degree. The consequences of the attacks of these rusts are not so serious in Uganda as in other countries where wheat-growing is a more staple agricultural industry. A third well-known wheat rust, that due to *Puccinia glumarum* Eriks. and Henn. and called yellow rust, occurs in Kenya, but has not yet been recorded in Uganda.

The pustules caused by black rust occur on most parts of the plant, the stalks, leaves, leaf-sheaths and even the ears, but they are not visible, as a rule, until the crop is well grown. The uredo-pustules are elongated and they may run together. When they rupture, they disclose beds of closely-packed uredospores The teleuto-pustules are later in development. They appear in streaks, and they in turn give rise

to numerous teleutospores. The uredospores are brown in the mass, and the teleutospores are black. It has already been mentioned that the function of a uredospore is that of ensuring immediate infection. When it is remembered that each pustule can produce hundreds of uredospores each of which causes on infection a new pustule which gives rise to successive fresh crops of spores during favourable weather, it is not difficult to understand how a field can become infected from one plant in a short space of time.

As already mentioned under maize rust, the teleutospores of black rust of wheat play in cold countries a well-defined and possibly essential part in the life-history of the fungus, but in Uganda, as in India, among hotter countries, all efforts to induce the teleutospores to germinate have failed. The teleutospores of black rust and the alternative host that they would infect, if they were capable of germinating, do not appear, therefore, to be indispensable factors in the carrying on of the rust from one crop of wheat to another. The stage of the life-history of the fungus which is found on the barberry after teleutospore infection is likewise unnecessary, and it may be observed that it has not been found in Australia and South Africa, in both of which countries black rust is common. Moreover, the black rust fungus, while it is known to exist on different plants, is divided within itself into distinct strains or races which are unable to pass from one plant to another; for example, the strain of black rust on wheat will not attack oats. It remains, therefore, to account in some other way for the apparently spontaneous outbreaks of black rust which commonly occur. The fungus may be carried over from crop to crop on stray wheat plants remaining by chance in the ground, or on wild grasses, though the latter are unlikely agents in view of the already-mentioned existence of specialised strains of the rust, or by uredospores which have fallen to the ground. The first and last methods of propagation are possible in this country when wheat succeeds wheat on the same plot of ground within a short time, but, on the whole, and particularly because of the actual small and scattered amount of wheat grown, cannot be sufficiently reliable in their action. A further theory, widely held and at the same time strongly criticised—the *mycoplasm* theory—accounts for outbreaks of black rust by supposing that the fungus is always present in an intimate and latent state in the protoplasm of the cells of the wheat plant, and that it is able to burst forth in the form of spore-bearing pustules when conditions are favourable for its doing so. Our concern, however, is not with the merits or drawbacks of this or that theory, but rather with the practical hints derived from the observations that have been made on black rust over many years, and these are, in short, that heavy soils, damp localities, and very close planting should be avoided. Climatic conditions have a strong influence on the incidence of black rust, and the weather that conduces to slow and steady growth is the most suitable for wheat in this or any other country.

Direct field treatment of black rust is impracticable, and the method of countering its bad effects that holds most promise is that of breeding resistant varieties of wheat. Great success has attended the efforts made in this direction in various parts of the world. The aim in breeding is to produce a variety which will resist the local rusts and also have such desirable characters as heavy yield and good-quality grain and straw. It has been found, however, that rust-resisting wheats become non-resistant in time and that varieties which are resistant in their home country or district are non-resistant when grown in a new environment. Such has been the case with varieties of wheat from India and Kenya imported into Uganda, so that, were wheat-growing to be taken up seriously in, say, Toro, where black rust occurs, breeding of resistant varieties and rust-resistant trials would have to be carried out in a scientific manner in the wheat-growing area. Since wheat-growing is entirely in native hands, present arrangements should include provision for the introduction of new varieties at intervals to be determined by the experience of the growers.

In Fig 9, No. 1 shows the appearance, greatly magnified, of the alternative stage of black rust on barberry. No. 2 shows a group of uredospores, and No. 3 a uredospore germinating. No. 4 shows teleutospores, and No. 5 a teleutospore germinating.

ORANGE RUST (*Puccinia triticina* Eriks.).—This rust is more common in Uganda than black rust and has proved itself more destructive. Its bright orange-coloured uredo-pustules form on the upper sides of the leaves in great profusion, as shown in Fig. 10, Nos. 1 and 2, but its teleuto-pustules, shown in No. 3, are much less common than the uredo-pustules and have been found only once. Orange rust can be distinguished from black rust by the colour and position of the pustules and by their remaining separate instead of coalescing to form lines. A second host of *Puccinia triticina* has been found in the United States in species of *Thalictrum* on which infection has been induced artificially, but it is unlikely that an alternative host plays any part in the life-history of orange rust in this country. An outbreak can be explained only on the theories already given in the discussion of black rust, but no real agreement on any one theory has yet been reached among mycologists. There is, likewise, nothing to add to the recommendations given under black rust.

LOOSE SMUT (*Ustilago tritici* (Pers.) Jens.).—Loose smut is not common in Uganda, and it cannot be said to be harmful. It has been found only on isolated plants. Its presence is shown when the ear begins to form. Infection takes place through the flower when the wheat is in bloom, and the fungus penetrates into the grain and lies dormant in the form of hyphæ until the next sowing season. When the

seed then germinates in the field, the internal hyphæ of the fungus keep pace with the growing-point of the young plant. As the time for the formation of the ear comes near, the fungus is found to have "fruited" by producing its black masses of spores and insinuating them into the place of the grain. The spores are easily scattered by the wind, and they again infect surrounding healthy plants by lodging on their flowers. Thus the cycle goes on from season to season. It is necessary for successful infection that the fungus should ripen its spores at the moment when the wheat field is in flower, and this is exactly what happens in nature. Smutted plants come into ear a short time before the rest of the crop. In Fig. 11, No. 1 shows a smutted ear, and No. 2 the same when the smut spore-masses have been blown away. No. 3 is a drawing of the spores magnified five hundred times, and Nos. 4 and 5 show their germination.

The most satisfactory treatment for loose smut is that of soaking the grain before sowing in water hot enough to kill the internal mycelium of the fungus without unduly damaging the grain. This treatment has proved satisfactory, but it is not necessary in this country so long as the percentage of smutted plants remains as low as at present. In dry weather, smutted plants should be destroyed, but in wet weather, even when the wheat is in flower, rain will wash the smut spores to the ground where they will germinate harmlessly, because, as already mentioned, they can infect fresh plants only through the flowers and the seed. For the same reason, the seed of a smutted crop of wheat should not be used for sowing. It is possible to eliminate loose smut from the small plots of wheat grown in Uganda by careful inspection of the growing plants and the timely removal of all suspects season by season.

LEAF SPOT (*Leptosphæria tritici* (Garov.) Pass.).—This wheat disease is not often found alone in this country, but it is invariably present on rusted leaves. It is characterised by yellow-brown spots, and it is sometimes called *black pricks* because of the development on the spots of the small black points shown in No. 1 of Fig. 12. The black points are the fructifications of the fungus. In No. 2 a single fructification, greatly magnified, is seen in section, and in Nos. 3 and 4 the younger and older spores contained in the fructification. In No. 5 a single spore is shown germinating. This stage of the black prick fungus is the only one found to date in Uganda. The perfect fruit, however, is known in Europe. Direct treatment of this disease is no more practicable than in the cases of the rusts, but all the indirect means, already given under black rust, of helping the plants to resist attacks should be adopted.

MOULD (*Cladosporium herbarum* Lk.).—Wheat mould is not common in this country, but, like the leaf spot fungus above, it has been found several times on rusted plants. It has occurred on leaves, stems, and ears. Its parasitism is

doubtful, for the fungus is a well-known saprophyte, and its attack on wheat seems to be confined to plants which have been already weakened by rust, especially by orange rust. Nevertheless, it may increase the damage done by, say, orange rust, by attacking the already-lessened numbers of grains, for mouldy grains give poor flour. In Europe, the fungus has been known to cause a serious blight in wet seasons. Any measure which will improve the growth conditions of the wheat will militate against the presence of this mould.

HELMINTHOSPORIUM LEAF SPOT.—A species of *Helminthosporium* has been found on wheat leaves along with orange rust Although its spores are slightly narrower, they seem to agree most nearly with those of *Helminthosporium sorokinianum* Sacc. which was recorded on wheat in Russia. The fungus is not of any importance, but, like the mould above, it may add considerably to the harm already done by the rust. It may be only a weak parasite for it is not known to occur independently, but its future appearances will be noted with interest, and a comparative study of the species of *Helminthosporium* known on maize, sorghum, and wheat may throw light on the conditions of their occurrence and parasitism in this country.

Bulrush Millet (*Pennisetum typhoideum* Rich.) *mawere*

RUST (*Puccinia penniseti* Zimm.).—This rust of *mawere* is common wherever the crop is grown in the Protectorate, but it is not destructive. It causes brown discolourations on the leaves and stems around the sites of the pustules. The pustules bear at first brown masses of uredospores, and, at a later date, black masses of teleutospores, and they are to be found on both leaf surfaces. In an average case, the uredo-pustules occur in small groups such as are shown on the left of Fig. 13. The drawing above depicts the appearance of the teleuto-pustules, while the two kinds of spores are shown below magnified about four hundred times. All attempts to germinate the teleutospores have been unsuccessful, and it is therefore likely that this rust, like the rusts of wheat and maize in this country, has lost its power of passing to an alternative host.

No special measures need be adopted in dealing with this rust, but the general recommendations already made will assist greatly in its control.

SPHACELIA DISEASE.—The presence of this disease is shown in no uncertain manner by the occurrence of large woody black or brown outgrowths on the ears and stems, usually at or near a node in the shelter of a leaf sheath. The outgrowths are distinctive in appearance and size, being at times as much as one inch across, and they cannot easily be overlooked or mistaken. They are technically termed *stromata*, and they are a stage in the life-history of a species of *Sphacelia* for they bear its spores. The perfect stage of the fungus

has not been found despite many attempts made to induce it to form, so that the affinities of this *Sphacelia* are not known. It was first described from German East Africa in 1904 on *Pennisetum spicatum*, and is common in Uganda on elephant grass (*Pennisetum purpureum* Schum.) as well as on the bulrush millet. It is thus confined to species of *Pennisetum* in this part of Africa, and it can probably pass from one host to the others. All cases of this disease up to date have been from *mawere* growing near elephant grass.

Affected plants may not set their seed, but the harm wrought by this *Sphacelia* disease has not been of much account. Stromata-bearing plants should be destroyed.

Millet (*Eleusine coracana* Gaertn.) *buro*.

Leaf Spot and Stem Disease.—The diseases of buro are not yet of any significance in the growth of the crop, despite the comparatively large areas of it that are cultivated in parts of the Protectorate. The fungi of the leaf spot and stem diseases are apparently weakly parasitic, if they are truly parasitic at all, for their attacks occur only when the crop is ripening, and they do not seem to influence to any harmful extent the maturing of the grain. The leaf spot is caused by *Phyllachora Eleusines* P. Henn. The stem disease is characterised by blackened areas on the lower internodes. These areas may be swollen or shrunken, and dissection reveals the presence of cavities full of mycelium corresponding in extent with the discolouration. The mycelium penetrates in plenty the surrounding tissues. When material is again available, it is hoped that future work will determine the time of attack of the fungus of the stem disease, whether early enough for its presence to interfere with the ripening of the grain, or late, in which case it cannot be regarded as a harmful parasite, or, in other words, whether the fungus is an active disease-producing agent or merely a weakly parasite whose presence is of little account. In either case, early-ripening varieties of buro are to be recommended for sowing, for they of necessity will suffer least from both the stem and leaf diseases.

Rice (*Oryza sativa* L.).

Blast Disease (*Piricularia oryzae* Br. and Cav.).—A general diseased condition of rice is common in Uganda. Up to date, the work devoted to it has established two facts of importance. The first of these is that the fungus, *Piricularia oryzae*, to which blast of rice is attributed by many scientific workers in different parts of the world, has been found in association with Uganda rice disease on the material obtained from different parts of the Protectorate for examination from time to time, and the second fact is that the diseased condition of rice has been reproduced in the laboratory by inoculation of healthy plants with *Piricularia oryzae* isolated from

diseased rice and grown in pure culture. There would thus seem to be a clear case against *Piricularia*. but, in addition to *Piricularia*, the following fungi have been found on Uganda rice:—*Gibberella saubinetii* (Mont.) Sacc.. *Fusarium roseum* Link. which is the conidial stage of the *Gibberella*, *Helminthosporium oryzae* Miy. and Hori. *Leptosphaeria Michotii* (West.) Sacc., *Leptosphaeria Iwamotsi* Miy., *Phoma glumarum* Ell. and Trac., *Epicoccum hyalopes* Miy., *Melanospora Zamiae* Corda and *Graphium stilboideum* Corda. No doubt the list could be greatly extended. Of these fungi, only the first four are of importance, and of these, again. only the second has been carefully studied, for the *Gibberella* was found only on one occasion and has since been searched for in vain. The *Fusarium* was proved by inoculation experiments not to be a disease-producing organism as far as rice was concerned. It is probable that the *Helminthosporium* and the *Leptosphaeria* are parasitic and harmful, but neither is present on diseased rice so frequently and so consistently as *Piricularia*. The position is, therefore, that, though future study may show that other fungi and perhaps other factors than the parasitism of fungi are involved in the production of the diseased condition of rice in Uganda, it is convenient at present to refer to it as if it were, as it may be, a state of affairs due to a single definite well-understood cause. For the above reasons, therefore, Uganda rice disease is recorded here as blast.

The blast of rice has been known for over two hundred years in Japan, and in Italy since 1560, but was not recorded definitely from Africa until two years ago, although it has doubtless been present in Uganda for several years. Its effects are so disastrous that it ranks with the grain rusts as one of the most serious plant diseases of the world.

The cultivation of rice in Uganda usually takes the form of small plots, and the kind of rice now grown is exclusively dry-land or mountain or high-land rice. Apparently the early difficulties encountered in endeavours to teach the natives to irrigate where facilities for irrigation were practically lacking led to the adoption of dry-land rice and to the exclusion of other kinds from cultivation. Imports of seed have been made at different times from India, Ukerewe Island on Lake Victoria (then part of German East Africa), the Congo Belge and Southern Nigeria, and rice has been grown in every part of the Protectorate at one time or another. Old reports on the progress of rice-growing in the different districts make mention of the occasional failure of the crop through small yields due to unfilled heads, and invariably attribute the failure to unsuitable land, unfavourable climatic conditions, or to lack of interest on the part of native growers who were in part non-grain-eaters. It may be remarked in passing that the symptoms of the blast disease resemble the effects of drought and poor soil. The early recommendations made to the chiefs and their people with regard to preparation of

land, sowing, and tending the crop were simple and sound, and it seems that, if they were carried out—and every effort to put them into practice was made through the medium of native travelling instructors—some other factor must have been at work to account for the disappointing results reported from time to time. It is impossible to say now whether this was so or not, or to determine the factor, for no investigations into the reasons for low yields or failure were carried out in the early days of rice-growing, but it is a striking fact that the same failure and low yields are encountered at the present day. In the meantime, the growing of rice has been taken up on a comparatively large scale in certain parts, particularly in the Eastern Province, and it is essential that the investigations into rice disease should be carried on and that those concerned with the natives who grow rice should be aware of the present position.

In blast disease, the leaves, stems, and ears of the rice are affected. Attention may first be called to the plants by a paling of the leaf-blades and the presence of leaf spots, usually longer than broad, but often extending across the leaf, red-brown at first and becoming pale-yellow. Spots are also to be found on the leaf-sheaths and particularly at the junctions between leaf-blades and sheaths. The stems are frequently affected at both nodes and internodes, usually the upper, and they may break over in consequence. A remarkable case of collapse occurred in January, 1922, in a small plot of *sathia* imported from India and grown at Bukalasa; the whole stand of plants was levelled as if it had been rolled by the bodies of large animals. The ears may appear normal, or the glumes may be discoloured in whole or in part with a grey to black area extending from the base upwards. The pedicels may be similarly discoloured, and the grains may be empty or partially or wholly filled. The attack of the fungus may occur early or late, and the resulting general appearance of an affected plot and the amount of grain carried may vary accordingly. Rice on the Government Plantation, Kampala, which was kept under close observation, has been attacked while quite young, and a proportion of the ears has been found, under the circumstances, empty or only half-filled, but it should be noted that such a plot may present a regular evenly-grown appearance and that only a close inspection of it in the field will reveal the presence of disease before harvest-time. Blast may manifest itself by an abnormal development of leaf spots, but this form has not often been found in Uganda.

A considerable amount of work on the susceptibility of different varieties of rice to blast disease has been done in various parts, but no variety has yet proved to be immune. In Italy, resistant varieties have been successfully grown, but experience has shown that all varieties tend to lose their resisting powers after continued growth in one locality.

Likewise, spraying and manuring have met with small local success but have not been found really helpful on the large scale required.

There is need, therefore, for the continual introduction into Uganda of new varieties, for the systematic transfer of varieties from one part of the country to another, for efforts to keep the best of them pure and unmixed, and for experimental work in the growing of them in the various rice districts. It has been found on the Government Plantation, Kampala, that irrigation of rice leads to a healthier stand of plants and a bigger yield, but it is questionable if this fact is of much consequence in a country where arrangements for irrigation are, on the whole, either difficult or impossible.

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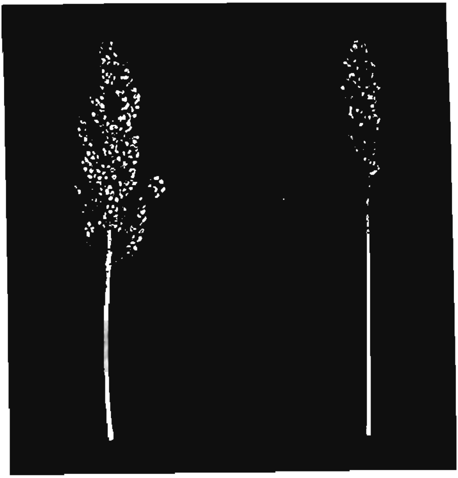
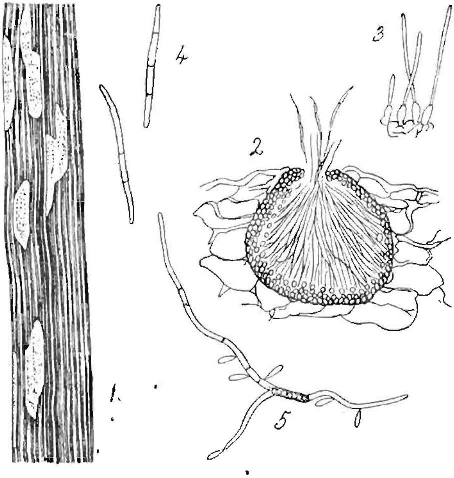
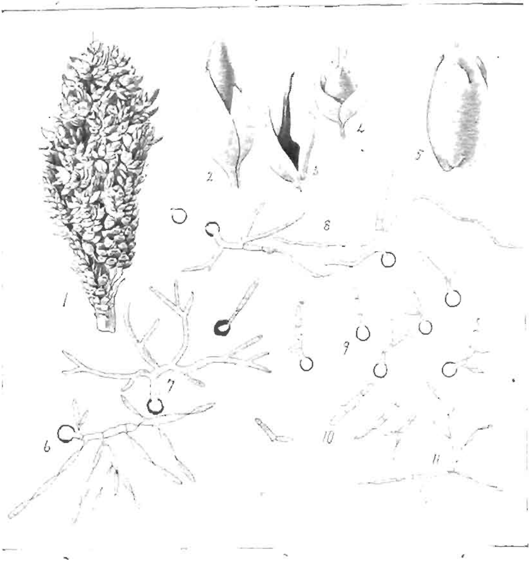


FIG. 1





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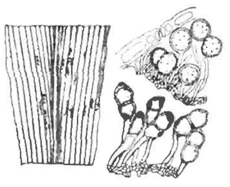
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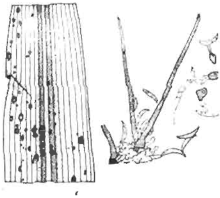
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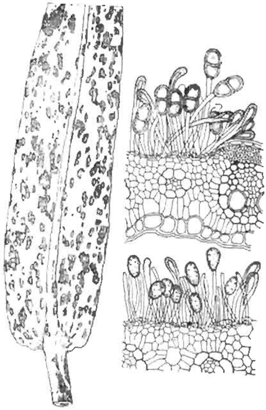

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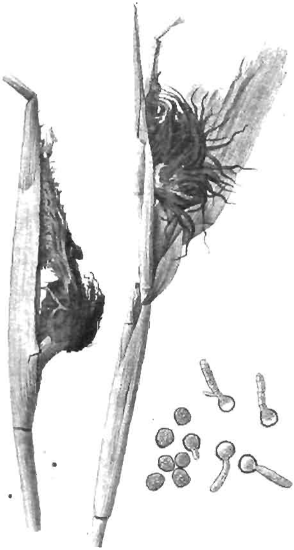
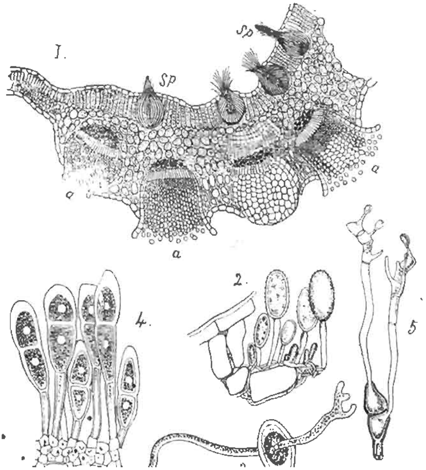


FIG. 6

FIG. 8



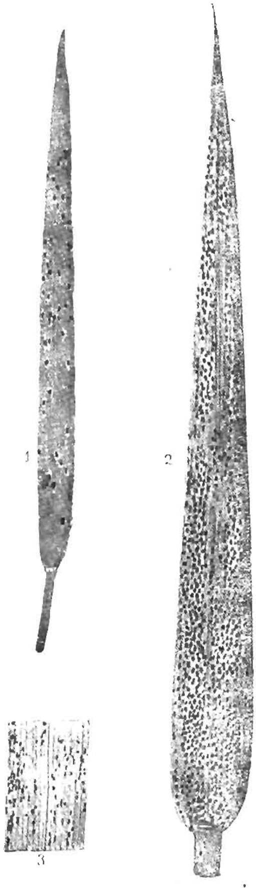


FIG. 10

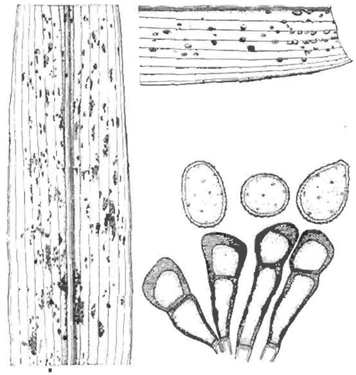



FIG. 11